

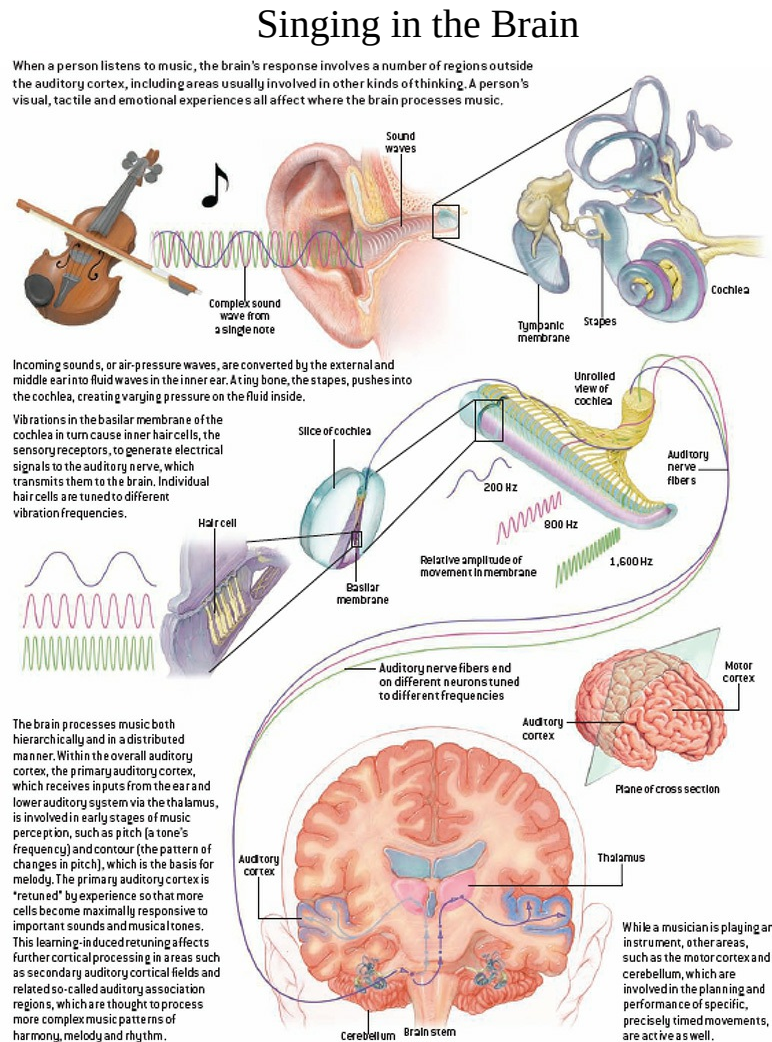
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Music & the Brain

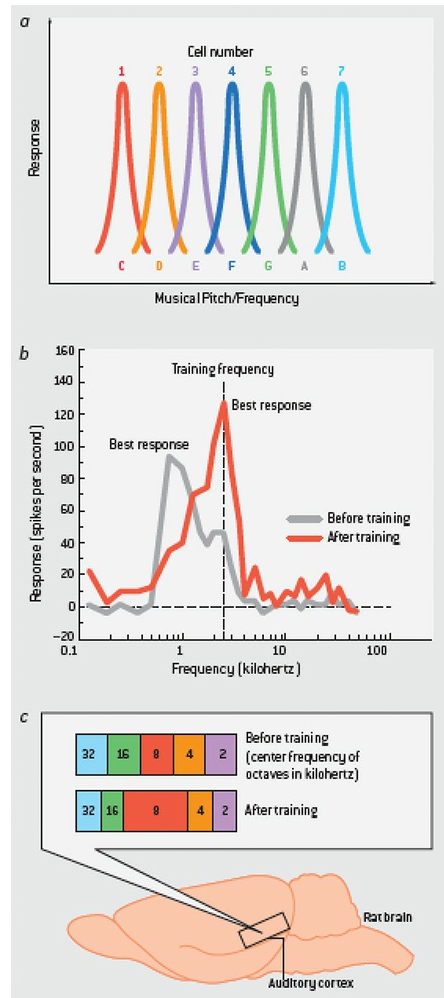


processed in the brain, which should lay a foundation for answering evolutionary questions. Collectively, studies of patients with brain injuries and imaging of healthy individuals have unexpectedly uncovered no specialized brain “center” for music. Rather music engages many areas distributed throughout the brain, including those that are usually involved in other kinds of cognition. The active areas vary with the person’s individual experiences and musical training. The ear has the fewest sensory cells of any sensory organ—3,500 inner hair cells occupy the ear versus 100 million photoreceptors in the eye. Yet our mental response to music is remarkably adaptable; even a little study can “retune” the way the brain handles musical inputs.



Credit: Illustration by Andrew Swift.

Inner Songs



Credit: Graphics by Laurie Grace.

Well-Developed Brains

Studies of musicians have extended many of the findings noted above, dramatically confirming the brain's ability to revise its wiring in support of musical activities. Just as some training increases the number of cells that respond to a sound when it becomes important, prolonged learning produces more marked responses and physical changes in the brain. Musicians, who usually practice many hours a day for years, show such effects—their responses to music differ from those of nonmusicians; they also exhibit hyperdevelopment of certain areas in their brains.

Christo Pantev, then at the University of Münster in Germany, led one such study in 1998. He found that when musicians listen to a piano playing, about 25 percent more of their left hemisphere auditory regions respond than do so in nonmusicians. This effect is specific to musical tones and does not occur

insights: “Relegating beauty to the study of art and leaving it out of science is no longer tenable.”

Evocative Equations

“Traditionally mathematicians have regarded simplicity as an important criterion for beauty,” explains neuroscientist Semir Zeki. The equation most frequently rated as beautiful by the mathematicians who participated in Zeki’s study was Leonhard Euler’s identity:

$$e^{i\pi} + 1 = 0$$

This equation relates the five most important mathematical constants with three basic arithmetic operations, each occurring once.

The equation that participants most often rated as ugly was Srinivasa Ramanujan’s infinite series for $1/\pi$:

$$\frac{1}{\pi} = \frac{2\sqrt{2}}{9801} \sum_{k=0}^{\infty} \frac{(4k)!(1103 + 26390k)}{(k!)^4 396^{4k}}$$

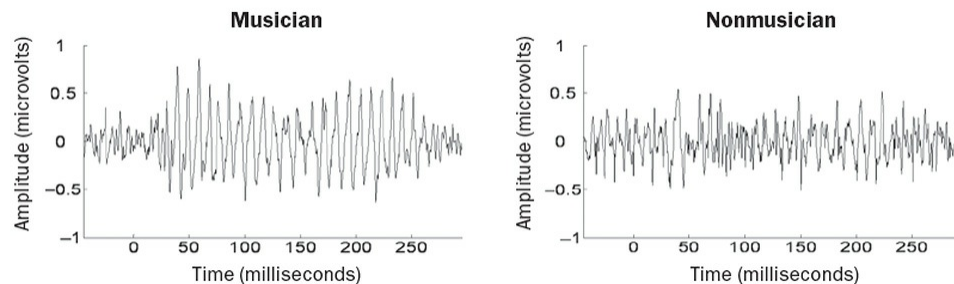
This equation defines the reciprocal of pi using integers, which is useful for mathematicians seeking to understand pi, one of the most important mathematical concepts.
—S.N.

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lessons also showed better reading ability than the children who had instead learned to paint, suggesting that facility with music may spill over into skill at deciphering the written word. Researchers have even suggested that musical training (in combination with other therapies) might be useful in remedying dyslexia.

Tuning the Brain

In a 2007 study scientists monitored the brain waves of people who were listening to recordings of words spoken in Mandarin. The study subjects, all English speakers, did not understand the meaning of what they heard. But the ones who had a music background showed a much stronger electrical response in a region called the auditory brain stem (*left*) than did those who had no musical training (*right*). The work suggests that learning to sing or play an instrument can make people more attuned to the melody of speech



Credit: Graph by Nina Kraus/Northwestern University.

Talking in Tune

Not only can exposure to music enhance our language skills, but the speech we hear also influences our perception of music. For example, in a musical illusion called the tritone paradox, which I discovered in the 1980s, a listener hears two computer-generated tones that are half an octave (or tritone) apart, one after the other. Each tone is a clearly defined note such as C, C-sharp or D, but its octave is inherently ambiguous so that a note could be, say, middle C, an octave above or below middle C, or any other C. The listener then decides whether the pattern ascends or descends in pitch. (Because of the ambiguity in the octave placement of the notes, there is no correct answer, and perception varies by listener.) Interestingly, I found that such judgments depend on the language or dialect to which the listener has been exposed. For example, in a 1991 study I asked people who had been raised in California and those raised in the south of England to judge these tritones and found that when the Californians tended to hear the pattern as ascending, the southern

pitch pattern. Below are examples of words that are phonetically identical but, depending on the pitches with which they are spoken, have four unrelated meanings. (Tone 1 is high and flat; tone 2 starts mid-high and rises; tone 3 starts low, falls and then rises; and tone 4 begins high and falls.) Each word is written with a distinct character.

Tone	Word	Chinese character	English meaning
1	mā	妈	mother
2	má	麻	hemp
3	mǎ	马	horse
4	mà	骂	reproach

Tone	Word	Chinese character	English meaning
1	wēn	温	warm
2	wén	闻	hear
3	wěn	稳	stable
4	wèn	问	ask

Tone	Word	Chinese character	English meaning
1	yāo	腰	waist
2	yáo	摇	shake
3	yǎo	咬	bite
4	yào	药	drug

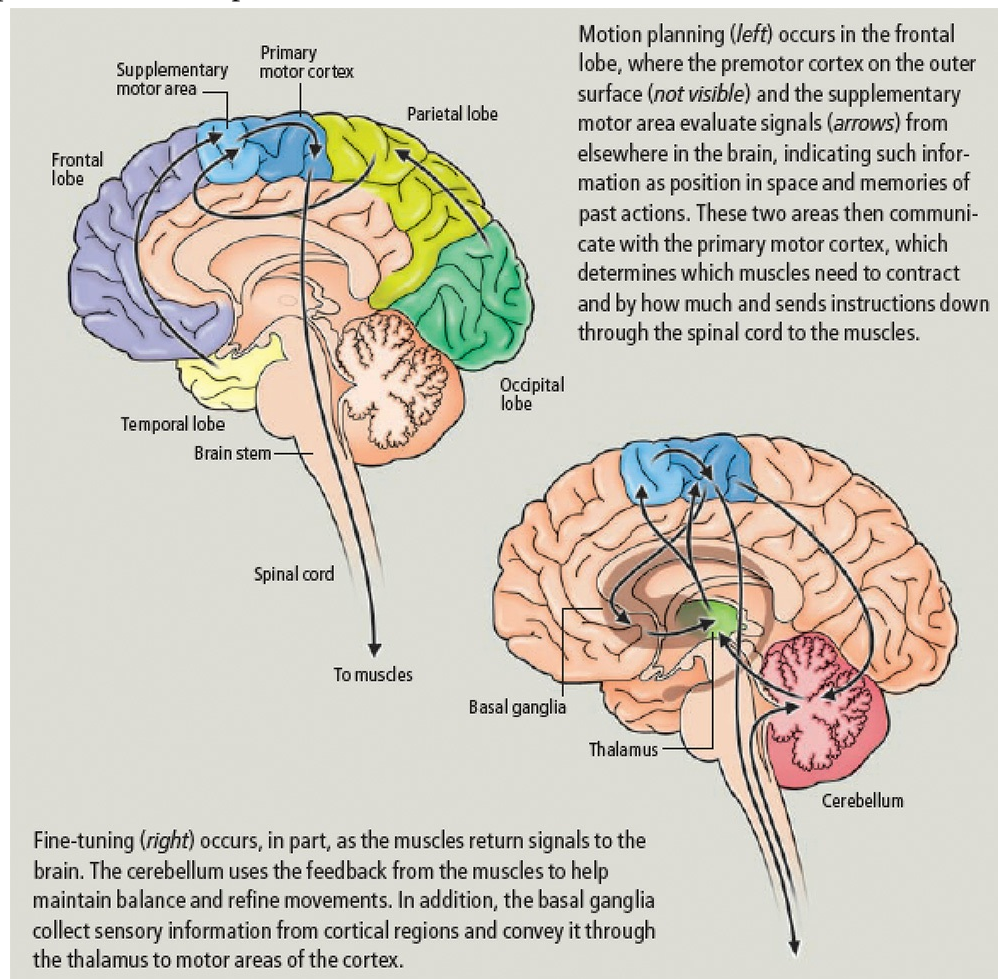
Tone	Word	Chinese character	English meaning
1	wēi	微	tiny
2	wéi	围	surround
3	wěi	尾	tail
4	wèi	喂	feed

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(July/August 2010).

synchronization and not simply listening. This finding led us to postulate a “low road” hypothesis that unconscious entrainment occurs when a neural auditory message projects directly to the auditory and timing circuits in the cerebellum, bypassing high-level auditory areas in the cerebral cortex.

The Brain's Moving Parts

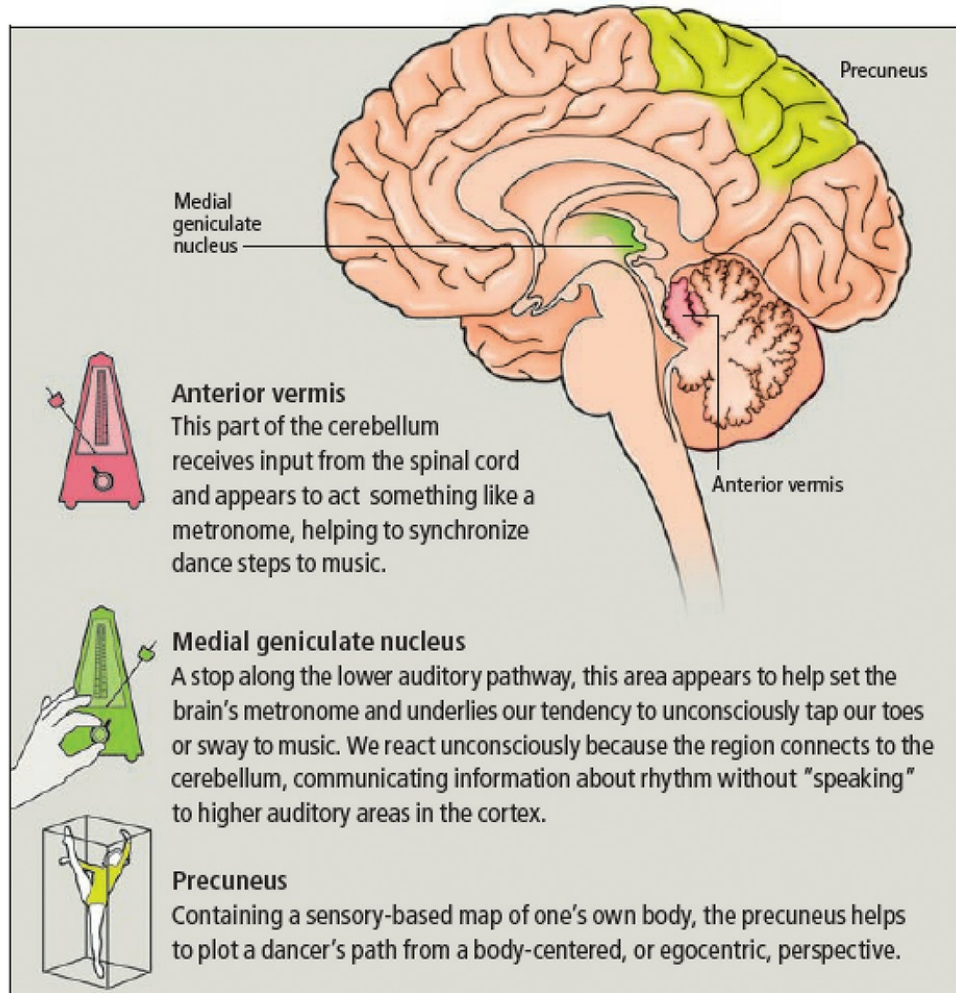
To identify the brain areas that control dance, researchers first need a sense of how the brain allows us to carry out voluntary movements in general. A highly simplified version is presented here.



Credit: Illustration by Tami Tolpa.

So You Think You Can Dance?

Other parts of the brain engage when we watch and learn dance movements. Beatriz Calvo-Merino and Patrick Haggard of University College London and their colleagues investigated whether specific brain areas become active preferentially when people view dances they have



Credit: Illustration by Tami Tolpa.

--Originally published: Scientific American 299(1); 78-83 (July 2008).